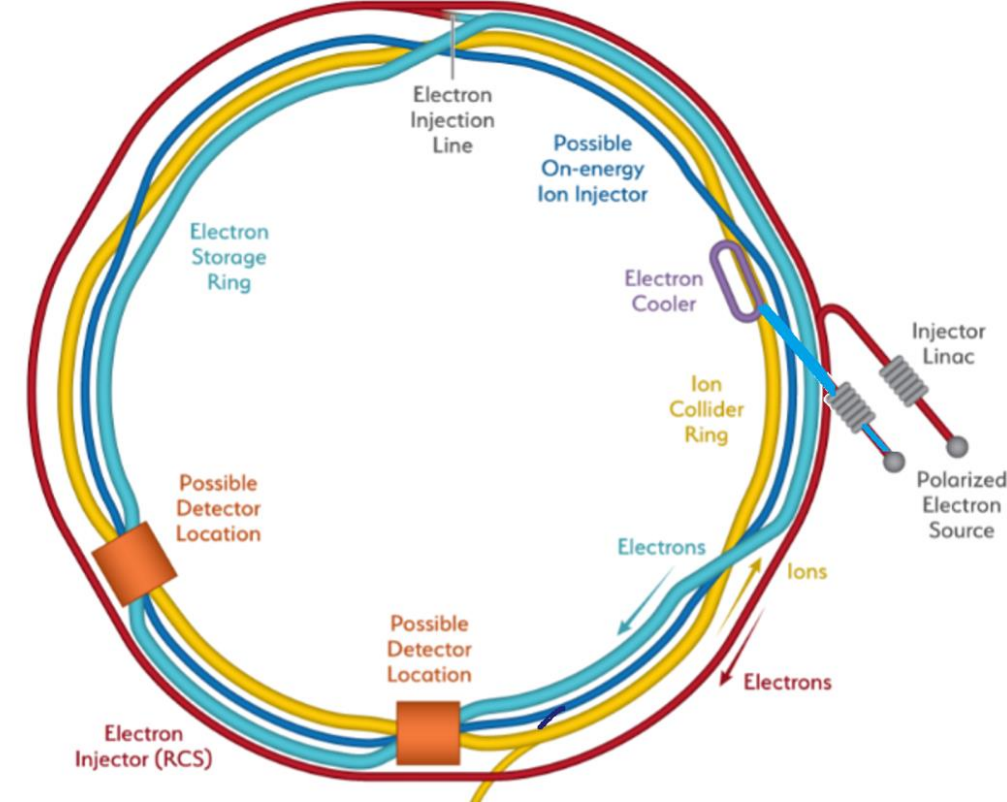# EIC Compton polarimeter -eRD26 status report-

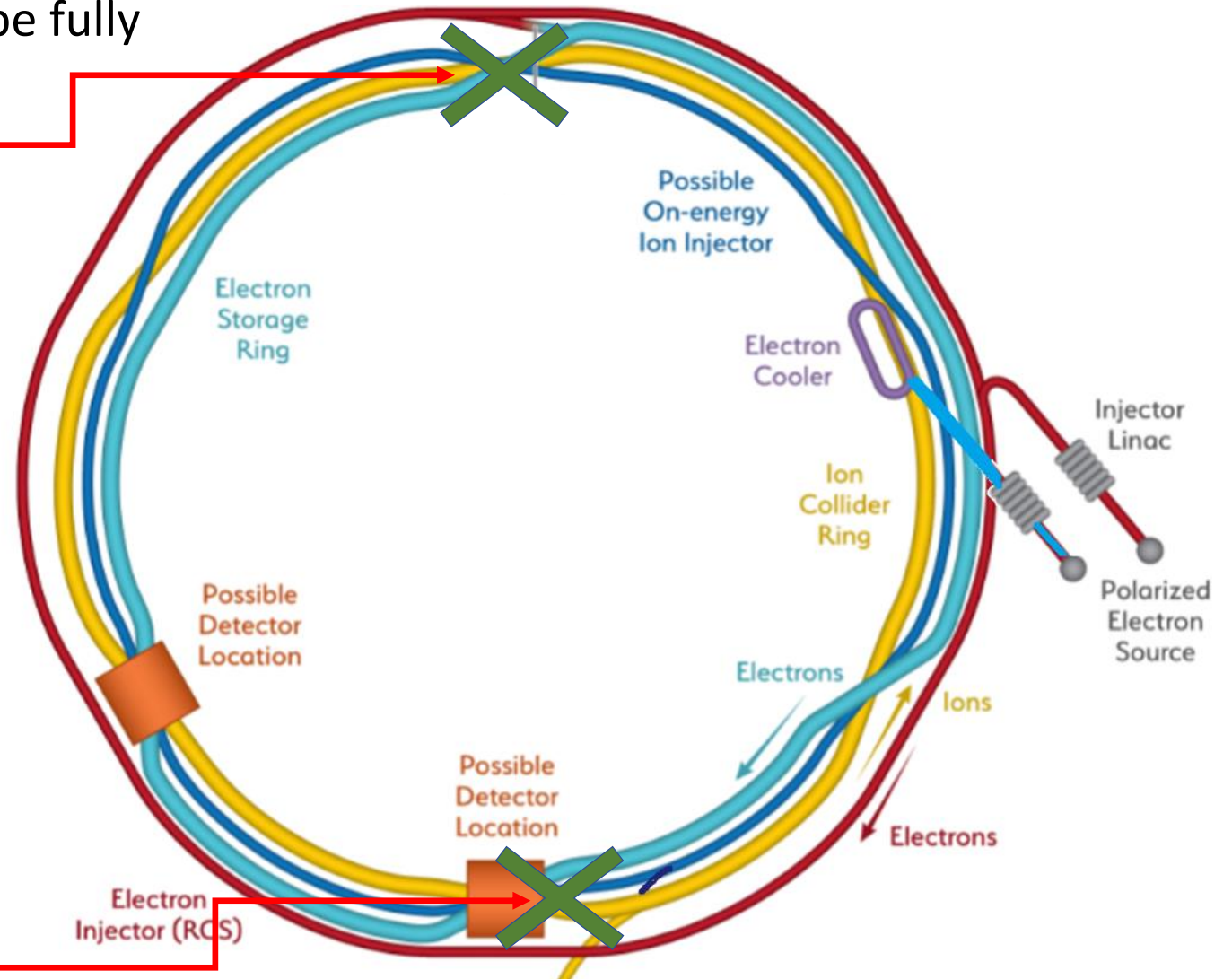Abhay Deshpande, Ciprian Gal*, Dave Gaskell, Caryn Palatchi, Kent Paschke, Shukui Zhang

Updates since last July

- Added one new member to the group: Caryn Palatchi (joint UVa – CFNS postdoc

- IP location change results in some significant changes in the analysis of the Compton polarimeter

- Identified and ordered components for the low power system needed for year 1

e-Polarimetry at the EIC

At the IP12 location beam will be fully transverse

Possible On-energy Ion Injector

Electron Storage Ring

Electron Cooler

Injector Linac

Ion Collider Ring

Polarized Electron Source

Possible Detector Location

Electrons

Ions

Possible Detector Location

Electron Injector (RCS)

Electrons

Close to the experimental IR it will be a mix (mostly longitudinal)

e-Polarimetry requirements for the EIC

Fast

- At 18 GeV bunches will be replaced every 2 min
  - A full polarimetry measurement needs to happen in a shorter time span
- The amount of electrons per bunch is fairly small ~24 nC
  - will need bright laser beam to obtain needed luminosity
- A fast polarimeter will allow for faster machine setup

Precise

- Distance between buckets is ~10ns (@5,10 GeV)
  - bunch by bunch measurement cannot be done with a CW laser without very fast detectors
- For systematic studies we would like to have the ability to either measure a single bunch (~78kHz) or have interactions with all 1160 (260) bunches at 10 and 5 GeV (18GeV)
- Backgrounds need to be under control
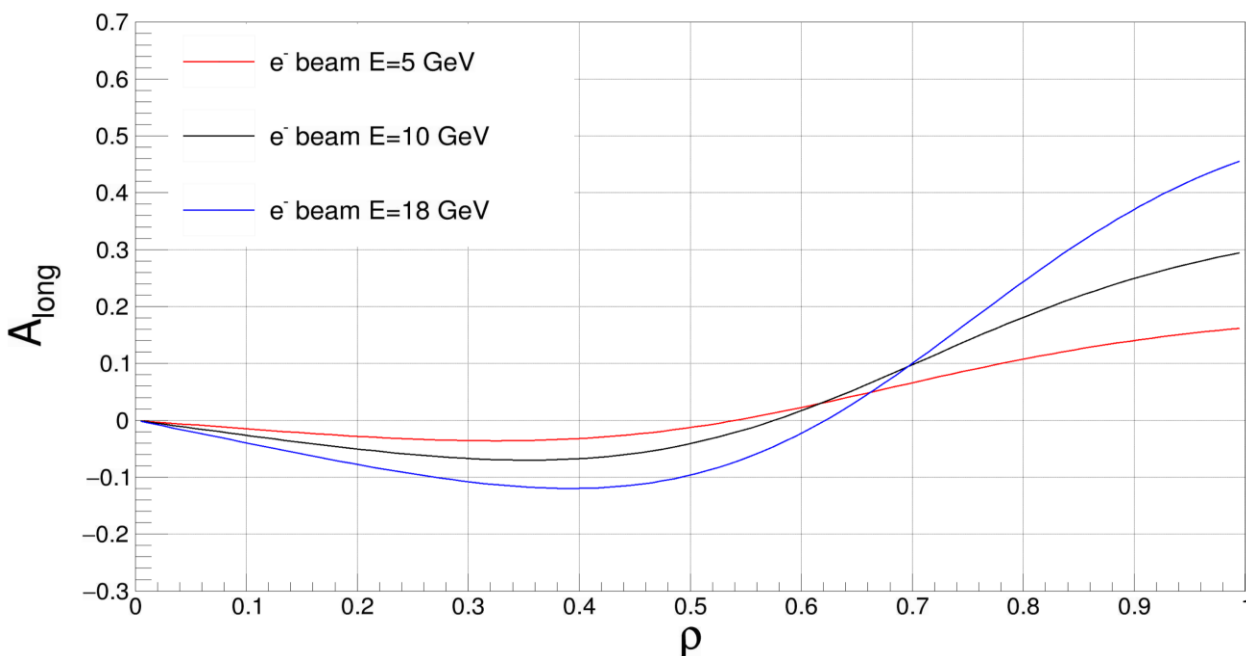- Laser polarization needs to be known to a high degree

Stony Brook University

Compton scattering basics
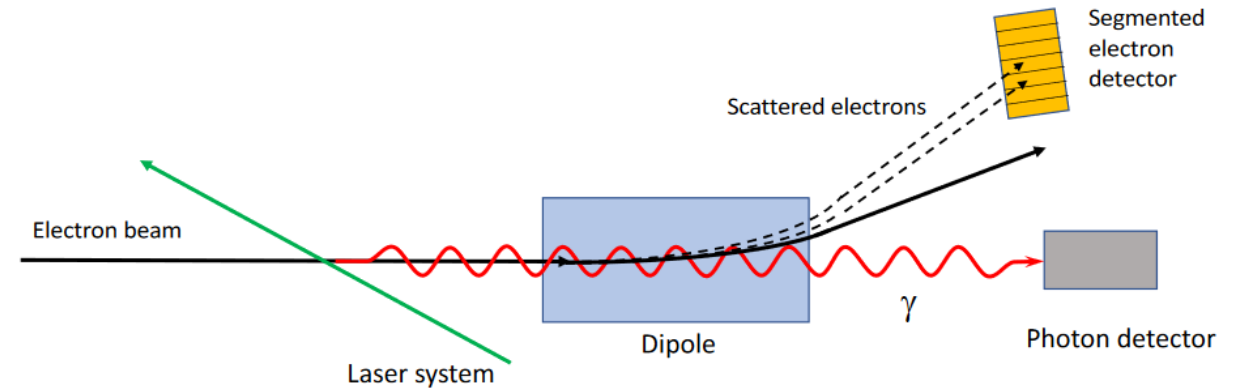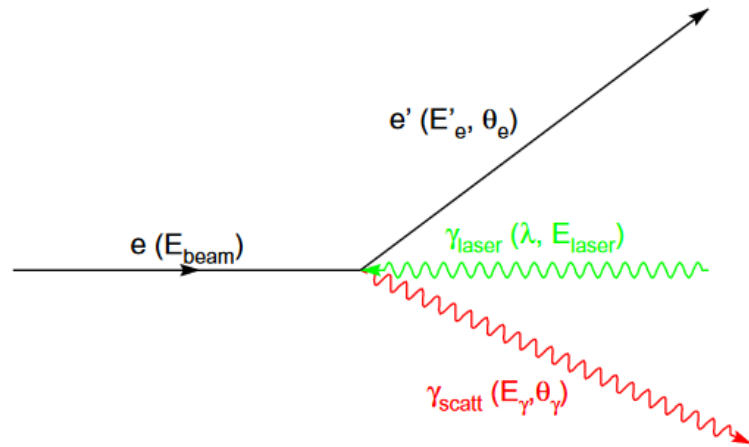
- Polarized photon-electron scattering

- Potential to measure redundantly with scattered photon and electron

- Fully QED calculable analyzing power

- Interactions happen with a small fraction of the beam particles leaving it undisturbed

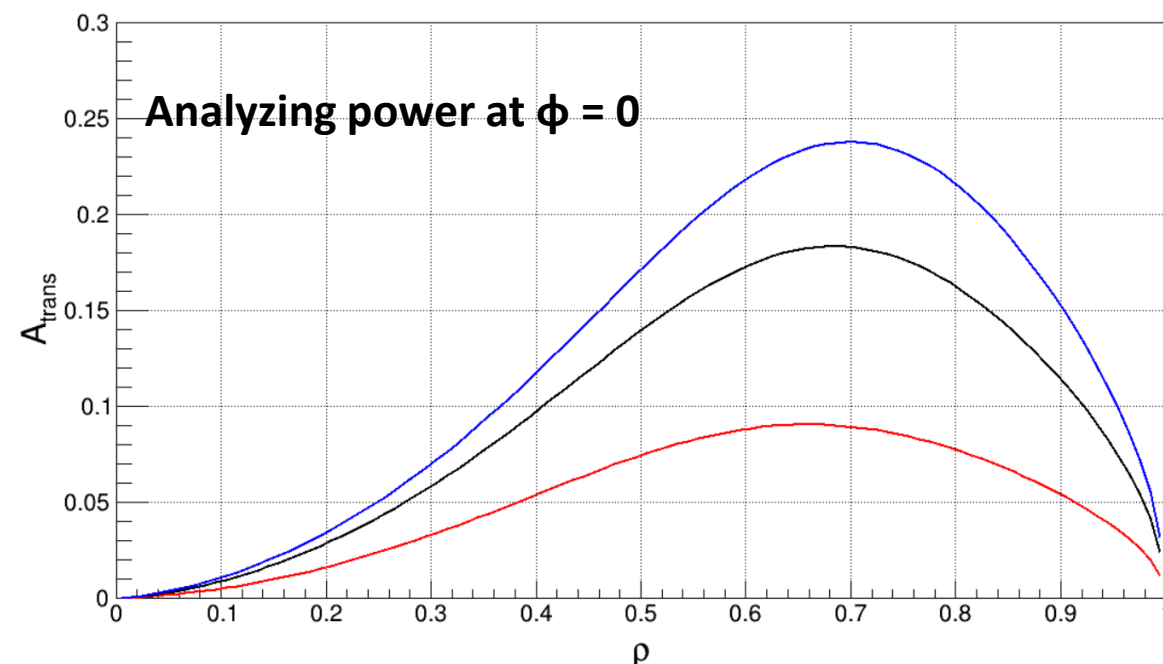 - Monitoring can be performed in real time during actual data taking

Compton scattering basics

$$A_{\text{long}} = \frac{\sigma^{++} - \sigma^{-+}}{\sigma^{++} + \sigma^{-+}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)}(1 - \rho(1+a))\left[1 - \frac{1}{(1 - \rho(1-a))^2}\right]$$

$$A_{\text{tran}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)}\cos\phi\left[\rho(1-a)\frac{\sqrt{4a\rho(1-\rho)}}{(1 - \rho(1-a))}\right]$$

Analyzing power at ϕ = 0

- Calculations based on 532nm laser system
- For both the longitudinal and transverse polarimetry measurements at the energies of interest for the EIC the analyzing powers are significant
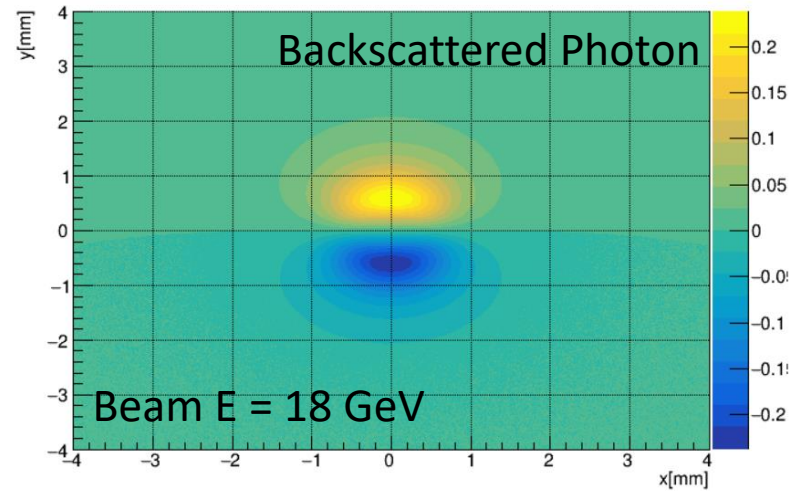
$$E_\gamma \approx E_{\text{laser}}\frac{4a\gamma^2}{1 + a\theta_\gamma^2\gamma^2}, \quad a = \frac{1}{1 + 4\gamma E_{\text{laser}}/m_e}.$$
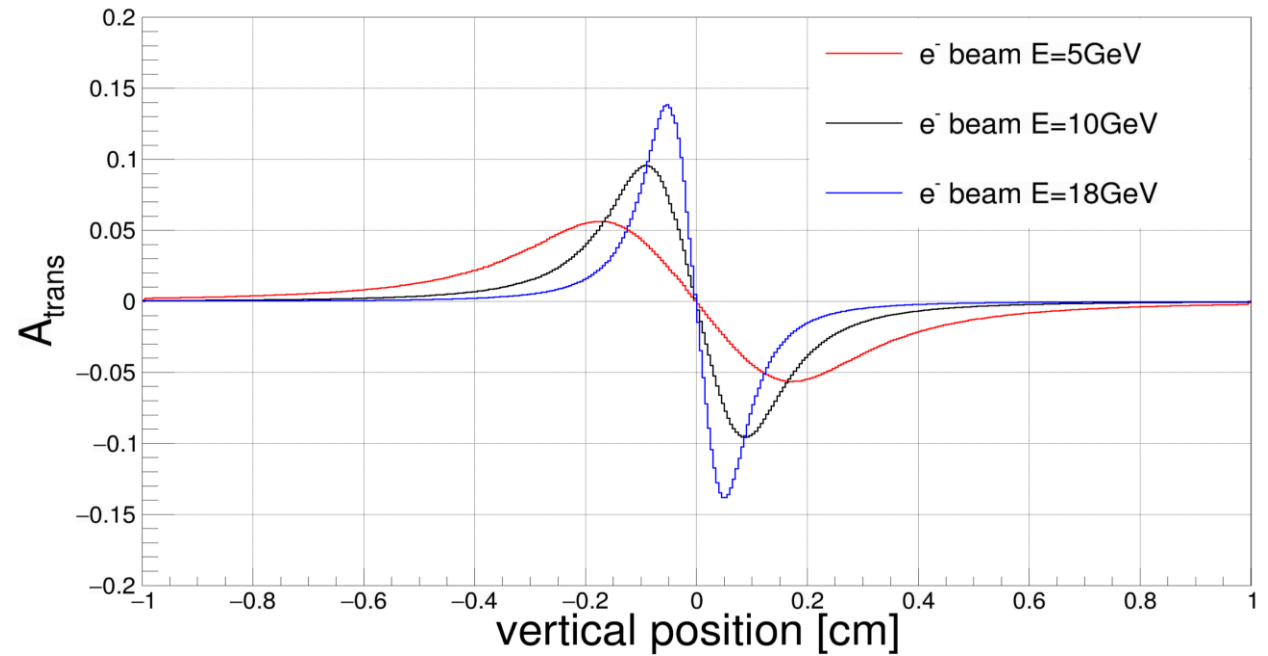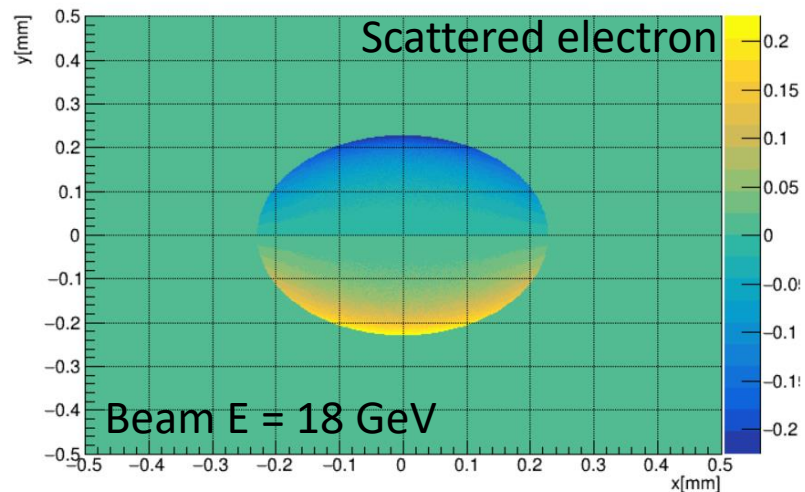
$$E_\gamma^{\text{max}} = 4aE_{\text{laser}}\gamma^2 \qquad \rho = E_\gamma/E_\gamma^{\text{max}}$$

Ciprian Gal

Transverse polarization

$$A_{\text{tran}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)} \cos\phi \left[\rho(1-a) \frac{\sqrt{4a\rho(1-\rho)}}{(1-\rho(1-a))} \right]$$

Backscattered Photon

Beam E = 18 GeV

electron polXsec z=25000 mm


Scattered electron

Beam E = 18 GeV

- Asymmetry is usually measured with respect to the vertical axis
  - The scattered electron reaches the largest analyzing power at large scattering angles
- The higher the energy the tighter the collimation of the scattered photons will be
  - This leads to significant constraints on detector segmentation

Ciprian Gal

IP6 polarization is more complicated

- The different beam energies will provide different amounts of longitudinal polarizations
  - This brings the analyzing power as a function of backscattered photon energy for all three configurations in a similar range

|	polarization at Compton IP	
Beam energy [GeV]	Longitudinal [%]	Vertical [%]
5	97.6	21.6
10	90.7	42.2
18	70.8	70.6
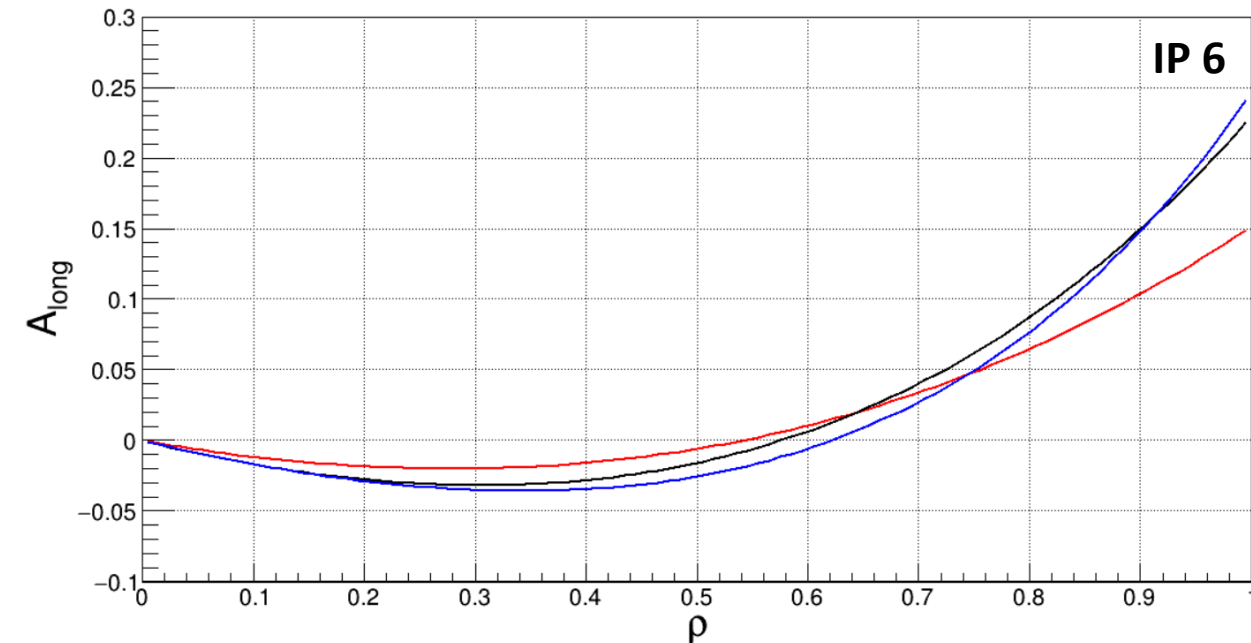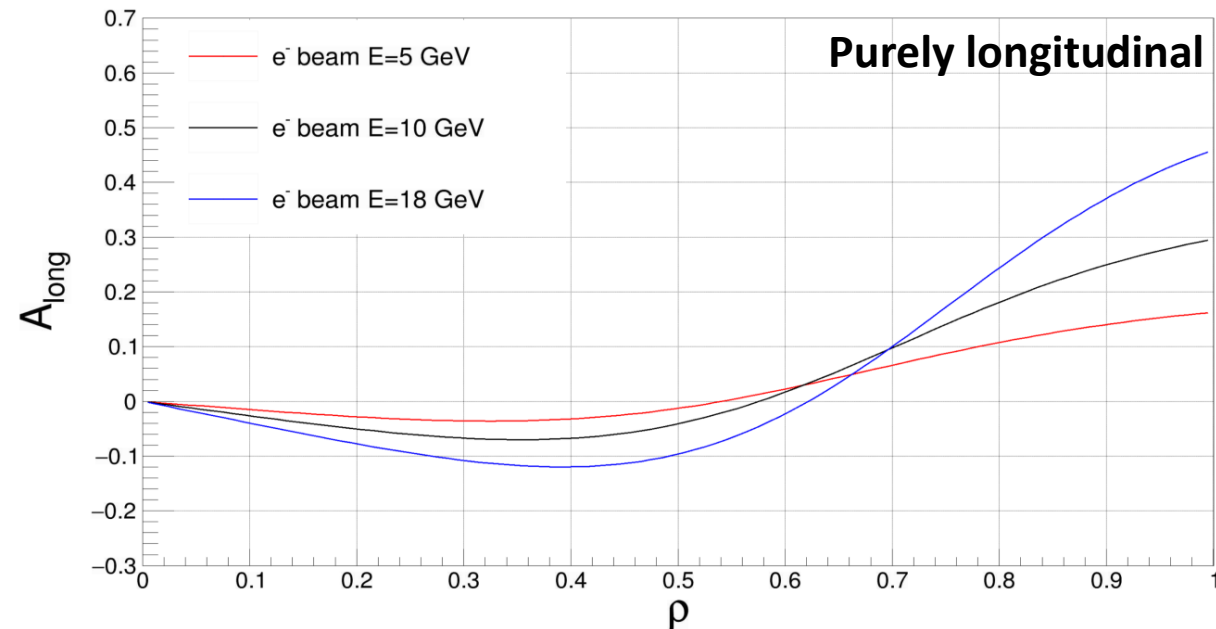
IP6 polarization is more complicated

- The up down asymmetry typically seen in transverse polarimeters is significantly more complicated for the IP6 configurations

- A detector system that can measure **both** longitudinal and transverse components will give us the best chance to obtain fast and precise polarization determinations

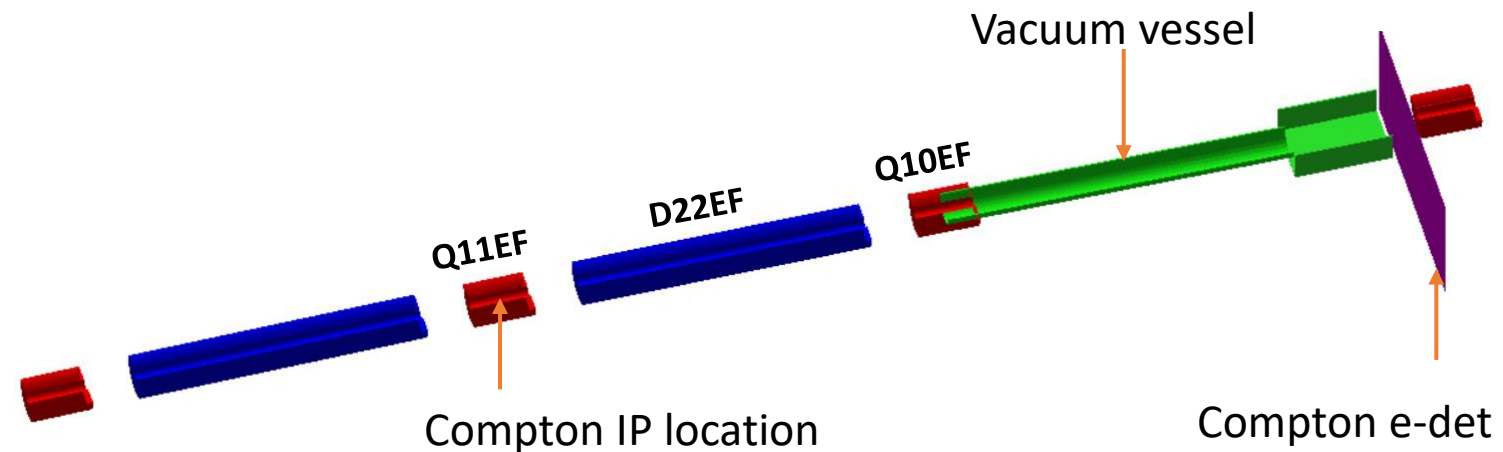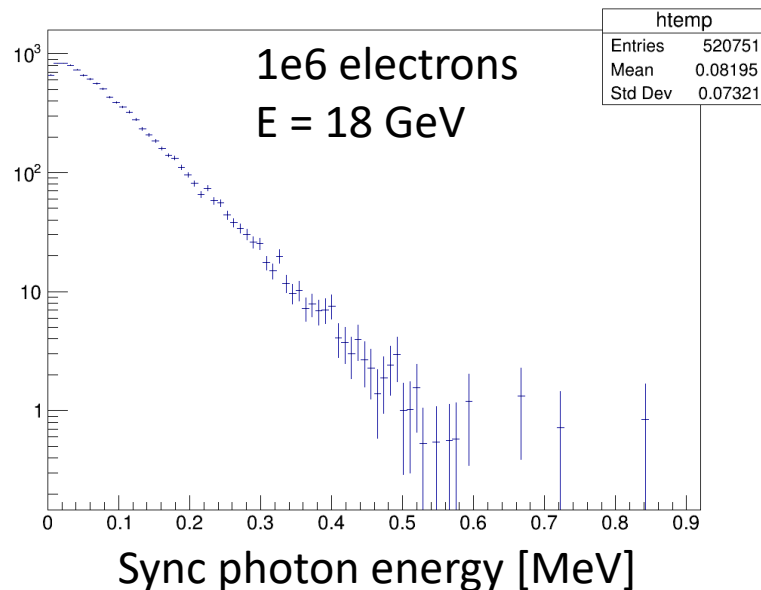|	polarization at Compton IP	
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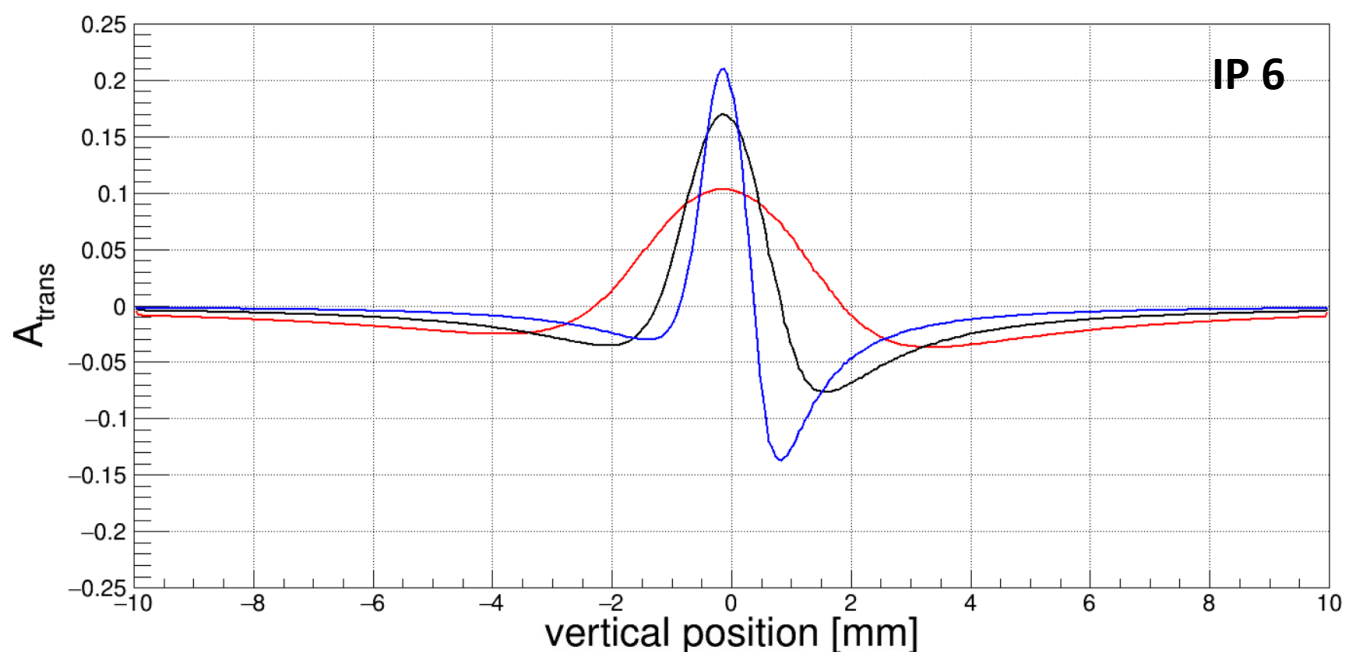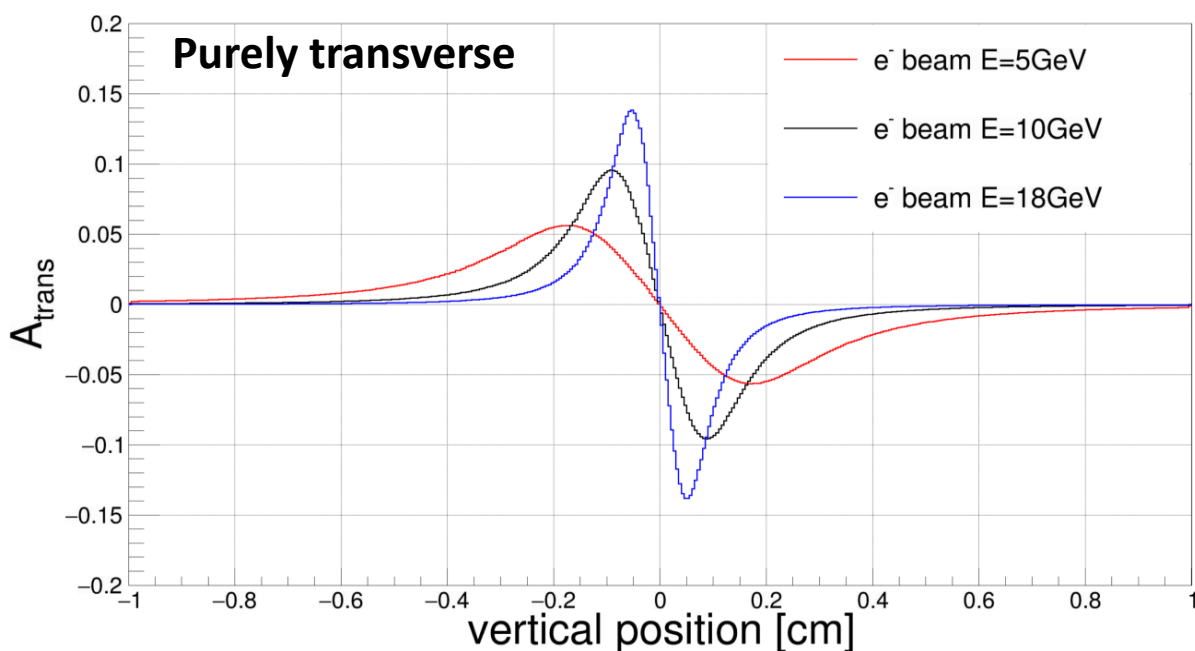
Synchrotron backgrounds (eRD15)

- M. Sullivan found that (in the JLEIC setup) the electron detector would get a significant amount of background at 7 and 10 GeV (with the expectation that it would be worse are higher energies)

- The EIC setup will suffer from a similar issue where 1-bounce photons would make it to the electron detector potentially being a significant source of background

- Of particular interest is the 18 GeV setup that will produce significantly higher energy photons
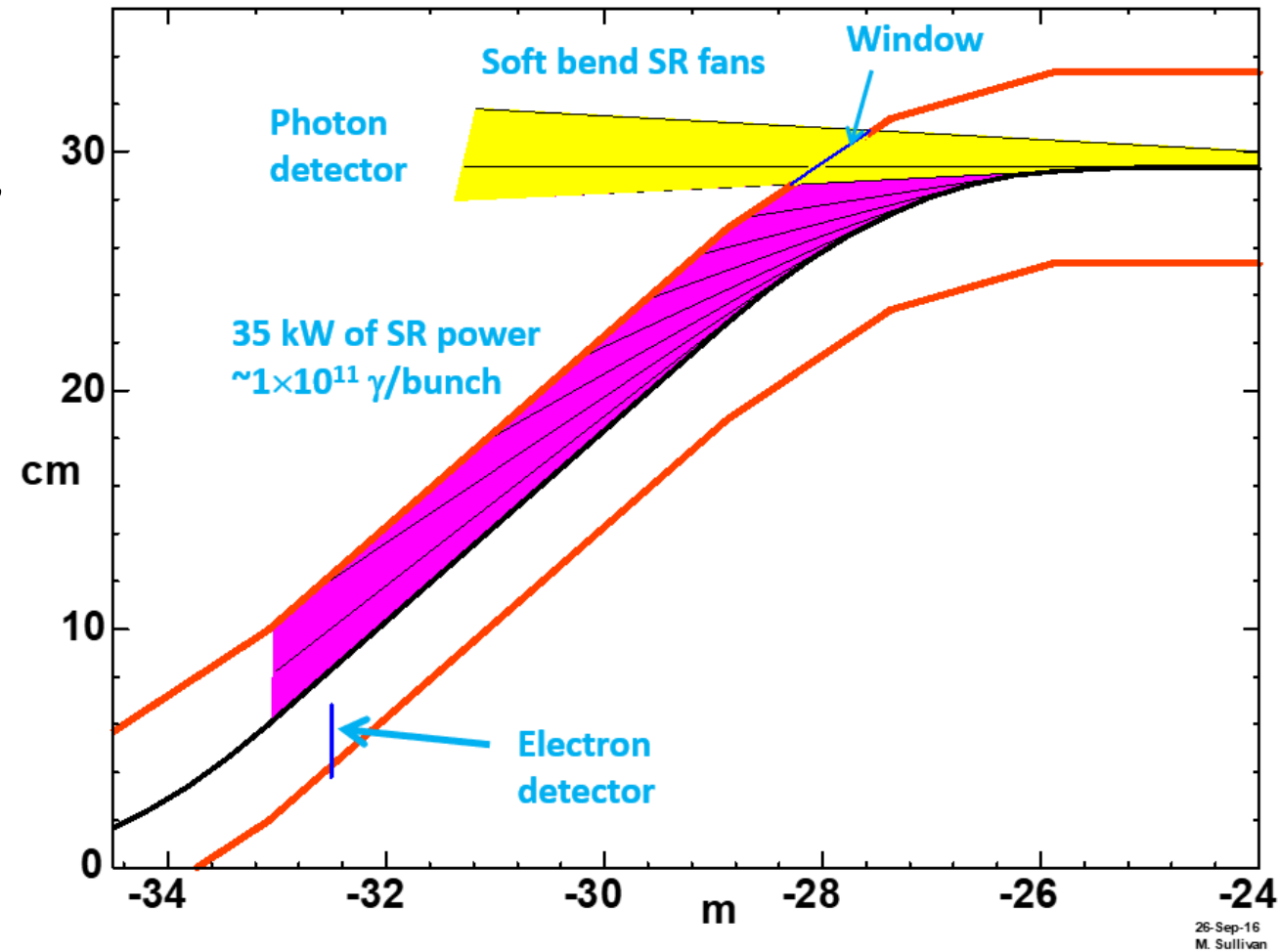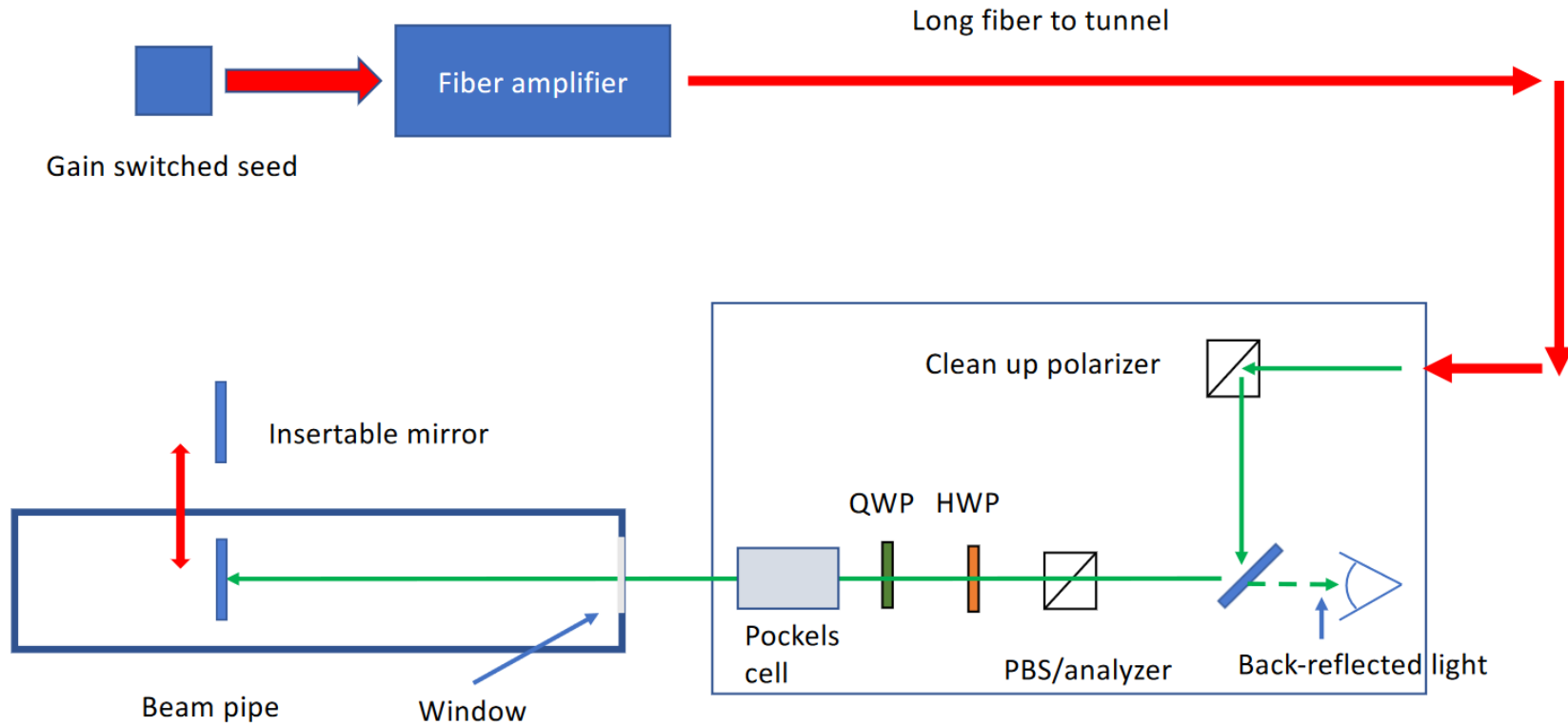
Synchrotron backgrounds

- We have started with the set up initially created by Zhengqiao Zhang (BNL) and added a rudimentary stainless steel pipe and box upstream of the electron detector location
- We have cross checked that the synchrotron spectrum provided by G4 is consistent with analytical calculations for a simpler set up
- The initial simulation doesn't show a significant amount of 1-bounce photons, but further cross checks will be made (including comparing our results to engineering calculations of power depositions on the beam pipe)
- The electron detector will need to be designed to be able to handle this background

1e6 electrons
E = 18 GeV

htemp	
Entries	520751
Mean	0.08195
Std Dev	0.07321

Sync photon energy [MeV]

Vacuum vessel

Q10EF

D22EF

Q11EF

Compton IP location

Compton e-det

Current design of EIC laser system

- The initial laser system design uses most of the design features highlighted in the previous Compton polarimeter implementations
  - As was before we need the laser system to be away from potential fatal radiation fields inside the tunnel (we plan to evaluate the use of high power laser fiber)
- The vacuum resident insertable mirror will be needed in order to be able to monitor the DOCP at the interaction point

Project and Deliverables

Year 1

- Detail design of laser system
- Seed and preamp construction
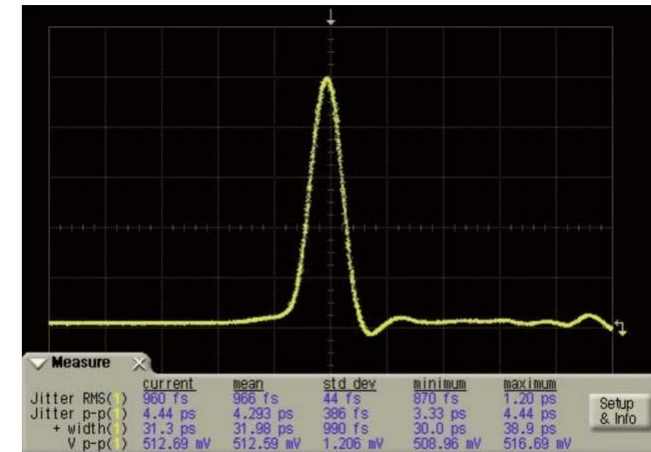 - Low power characterization

Year 2

- High power fiber amplifier
- Fiber delivery
- Frequency doubler
- Design vacuum system

Year 3

- Check 100% DOCP laser polarization through vacuum windows
- Remote control stages
- Picomotor controller
- Potential test at JLab
- Publish results

Stony Brook University

Components identified

- The most important components for the variable pulse frequency are the seed laser and the pulse generator
- We have decided to use Cybel LLC for both of these components as they have been used in similar systems at LERF (JLab)
- The average laser output power (pulsed/100MHz): 0.1 mW
- The pulse generator can give us tunable pulse width and a wide frequency range
- We expect delivery by early June
  - This should allow us to complete the low power proof of principle by the end of the funding cycle
- Additional "off-the-self" (Thor Labs or Newport) components were identified: controllers for the seed (ITC4002QCL/LDT-5910C-120V & LDX-3412-120V), pre-amplifier (YDFA100P), various fiber optics (IO-G-1064, PM100D, S121C)
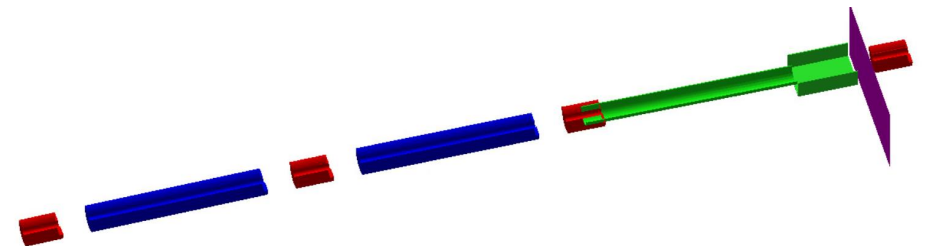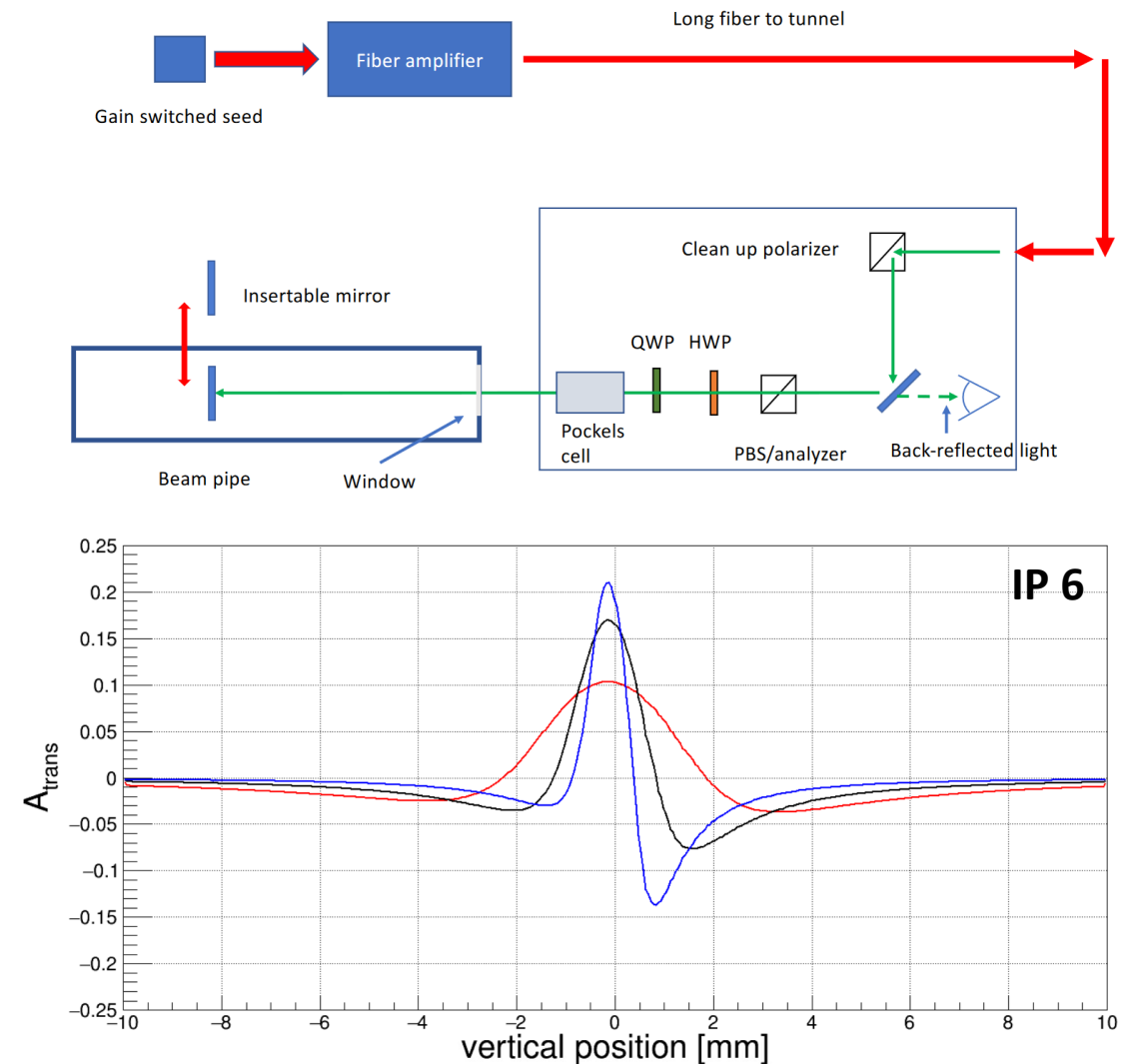

Cybel-LLC
EPG-210 Module

QLD106G-6410 by Cybel-LLC
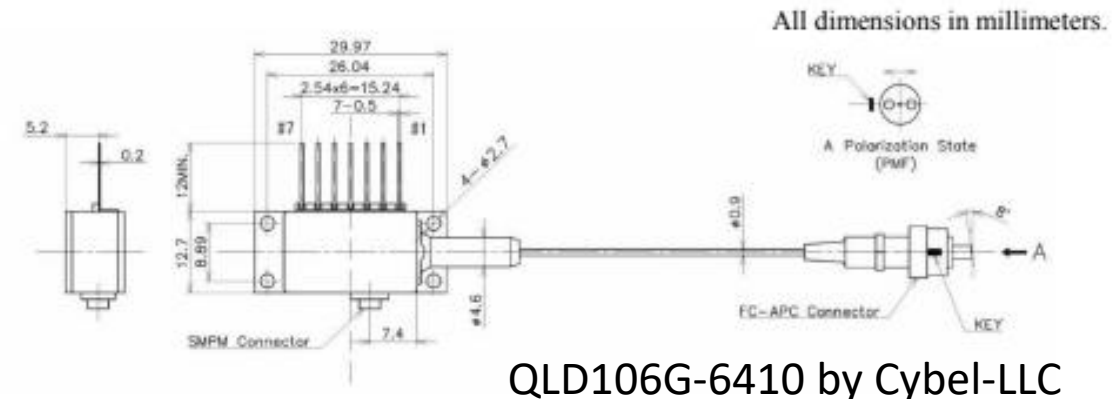
Summary and next steps

- After the low power variable frequency characterization the crucial step of taking the system to high power will need to be done in the second year

- The IP6 locations provides unique challenges, especially taking into account the lofty goal of 1% precision

- In parallel with the determination of the detector requirements and analysis technique we will push ahead with the evaluation of backgrounds for both the electron and photon detectors

Backup